Fact Sheet

MEASURING THE ADHESION STRENGTH OF ICE

PROBLEM

Icing of surfaces and components adversely affects aircraft, marine vessels, surface vehicles, communication and power delivery systems, hydroelectric intakes, and a host of other critical systems. The lack of a standardized method for testing the adhesive strength of ice has hampered efforts to develop low-adhesion materials. Ice adhesion has been measured by a number of researchers in a variety of ways but the results are relatively scattered and difficult to compare because adhesion strength is sensitive to subtle differences in test parameters (e.g., temperature, loading rate, substrate type and roughness, ice crystal size and orientation, etc.).

SOLUTION

After several years of research, we have developed a laboratory facility for measuring the bond strength of ice in a relatively simple manner. We have found that attention to sample preparation and handling in conjunction with careful control of sample growth and test conditions leads to reproducible results. We are equipped to test and analyze the results from 12 samples in three days. We can also assess the durability of low-adhesion materials by repeated shear testing.

Our method has been adapted from the Zero Degree Cone Test for adhesive joints. We grow ice in the annular gap between two concentric, cylindrical surfaces and then measure the force required to push the inner cylinder, or pile, out of the ice collar and outer cylinder. An O-ring, installed on the bottom of the pile, keeps the degassed, distilled water from leaking out while it freezes. The samples require about eight hours to freeze completely at a temperature of -10° C, and we allow another 40 hours for the internal stresses to relax before testing. We test the samples using a materials testing machine whose feed rate is accurately maintained by feedback control.

RESULTS

We conducted baseline tests of ice adhered to stainless steel piles, having an rms surface finish of 5–15 μ in, at four different strain rates ranging from 4.2 to 400×10^{-6} s⁻¹. We found that, through this range, the ice behavior transitioned from viscoelastic to ductile, and that the mean adhesive strength increased from 70 to 600 kPa as we increased the strain rate. We have determined that the shearing occurs cleanly at the pile/ice interface. In terms of repeatability, the standard deviation in the shear stress decreased with increasing strain rate and was consistently below 20% of the mean values.

This testing facility is now available for us to compare the relative performance of commercially available coatings for their ability to aid in ice removal.

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